COMBUSTION ENGINEERING

February 22, 1990
LD-90-017

Docket No. 71-6294

Mr. Charles E. MacDonald, Chief
Transportation Branch
Division of Safeguards and Transportation
Office of Nuclear Material Safety and Safeguards
U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D. C. 20555

Subject: Revision to UNC-2901 Shipping Container Certificate of Compliance Amendment Request

Reference:
(A) Letter, LD-90-012, A. E. Scherer (C-E) to C. E. MacDonald (NRC), dated February 14, 1990

(B) Letter, LD-89-132, A. E. Scherer (C-E) to C. E. MacDonald (NRC), dated November 22, 1989

(C) Letter, LD-89-135, A. E. Scherer (C-E) to C. E. MacDonald (NRC), dated December 5, 1989

(D) Letter, LD-89-004, A. E. Scherer (C-E) to C. E. MacDonald (NRC), dated January 18, 1989

Dear Mr. MacDonald:

In our letter, Reference (A), Combustion Engineering requested that you temporarily suspend review of the References (B) and (C) amendment packages for the UNC-2901 shipping container. This letter provides a replacement amendment package which supersedes both References (B) and (C) and revises pages in our original Reference (D) amendment package.

The revision resulted from Combustion Engineering's determination that a design modification was necessary and that the modification would invalidate material formerly submitted. While the final design is still in progress, Combustion Engineering has reformulated the

R-45

Power Systems
Combustion Engineering, Inc.

FEB 26 1990

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amendment request to eliminate the affected material. Specifically, this amendment request only addresses the shipment of UO2 pellets in the UNC-2901 shipping container. Reference to the shipment of UO2 powder has been deleted at this time. We have taken this step in the hope that it will allow a more expeditious review of the remaining material. Combustion Engineering has a need to ship greater than the currently approved 4.1 wt % pellets on or about the the latter part of April, 1990.

Enclosure I provides a tabulation of the revised application pages. Enclosure II provides the change pages. Ten (10) copies of the enclosures are provided for your use.

Combustion Engineering apologizes for any inconvenience this situation may have caused. If I can be of further assistance, please do not hesitate to call me or Mr. C. M. Molnar of my staff at (203) 285-5205.

Very truly yours,

COMBUSTION ENGINEERING, INC.

A. E. Scherer
Director
Nuclear Licensing

AES:jeb

Enclosures: As stated

cc: R. Chappell (NRC)
G. France (NRC - Region III)
D. McCaughey (NRC)
N. Osgood (NRC)
J. Roth (NRC - Region I)

Enclosure I to
LD-90-017

COMBUSTION ENGINEERING, INC.

CERTIFICATE OF COMPLIANCE NO. 6294

UNC-2901 SHIPPING CONTAINER

LIST OF AFFECTED PAGES

FEBRUARY, 1990

UNC-2901 SHIPPING CONTAINER
CERTIFICATE OF COMPLIANCE NO. 6294
AMENDMENT REQUEST

Combustion Engineering requests that Certificate of Compliance No. 6294 for the UNC-2901 shipping container be amended to reflect changes in container usage. This amendment requests approval for the shipment of UO_2 pellets and hard scrap up to 5.0 wt % U235. The revised pages provided herewith amend pages in our submittal of January 18, 1989 (LD-89-004) and they replace, in their entirety, materials submitted by our letters of November 22, 1989 (LD-89-132) and December 5, 1989 (LD-89-135). The affected pages are provided in Enclosure II.

The Certificate of Compliance application pages affected by this revision, their submittal date and revision numbers are listed below:

Delete Page			Add Page		
Page No.	Rev.	Date	Page No.	Rev.	Date
ii	0	01/18/89	ii	0	02/22/90
iii	0	01/18/89	iii	0	02/22/90
1-1	0	01/18/89	1-1	0	02/22/90
1-2	0	01/18/89	1-2	0	02/22/90
1-3	0	01/18/89	1-3	0	02/22/90
1-4	0	01/18/89	1-4	0	02/22/90
1-5	0	01/18/89	1-5	0	02/22/90
1-6	0	01/18/89	1-6	0	02/22/90
1-7	0	01/18/89	1-7	0	02/22/90
1-8	0	01/18/89	-	-	--
1-9	0	01/18/89	-	-	--
1-10	0	01/18/89	-	-	--
1-11	0	01/18/89	-	-	--
1-12	0	01/18/89	-	-	--
6-1	0	01/18/89	6-1	0	02/22/90
6-2	0	01/18/89	6-2	0	02/22/90
6-3	0	01/18/89	6-3	0	02/22/90
6-4	0	01/18/89	6-4	0	02/22/90
6-5	0	01/18/89	6-5	0	02/22/90
6-6	0	01/18/89	6-6	0	02/22/90
6-7	0	01/18/89	6-7	0	02/22/90
6-8	0	01/18/89	6-8	0	02/22/90
6-9	0	01/18/89	6-9	0	02/22/90
6-10	0	01/18/89	6-10	0	02/22/90
6-11	0	01/18/89	6-11	0	02/22/90
6-12	0	01/18/89	6-12	0	02/22/90
6-13	0	01/18/89	6-13	0	02/22/90

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Page No.	Rev.	Date	Page No.	Rev.	Date
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6-17	0	01/18/89	6-17	0	02/22/90
6-18	0	01/18/89	6-18	0	02/22/90
6-19	0	01/18/89	-	-	--
6-20	0	01/18/89	-	-	--
6-21	0	01/18/89	-	-	--
7-1	0	01/18/89	7-1	0	02/22/90
7-2	0	01/18/89	7-2	0	02/22/90

Enclosure II to
LD-90-017

COMBUSTION ENGINEERING, INC.

CERTIFICATE OF COMPLIANCE NO. 6294

UNC-2901 SHIPPING CONTAINER

AMENDMENT REVISION CHANGE PAGES

FEBRUARY, 1990

APPLICATION FOR USE OF
SHIPPING CONTAINER MODEL NO. UNC-2901
FOR THE
TRANSPORT OF SPECIAL NUCLEAR MATERIAL

TABLE OF CONTENTS

1.2.2 Operational Features

The UNC-2901 shipping container is of relatively simple design, and does not incorporate cooling systems, shielding, etc.

1.2.3 Contents of Packaging

1.2.3.1 Pellets or Rejected Pellets

Maximum Enrichment 5.0 wt.%
Type Material: Sintered (high fired) uranium oxide pellets.
Maximum quantity per container:

a) Maximum net weight:
Maximum net weight of pellets: 320 pounds
Pellets and packaging material (contents of inner container) 427 pounds.

b) Gross Weight:
Gross weight of the container as assembled for shipment shall not exceed 660 pounds.

1.3 Appendix

Details of construction and assembly are shown on drawings:

a) D-5007-8086, Rev. 05, S.W.O.P.P. Upgrade UNC 2901 Shipping Drum for UO_2 Powder & Pellets Assembly & Details
b) B-5007-8112, Rev. 01, Suggested Assembly of 2901 Plywood Insert
c) D-5018-2001, Rev. 01, Pellet Shipping Package
d) NFM-D-4263 Rev. 02, Pellet Tray Holder
e) NFM-D-4540, Rev. 00, UNC 2901 Shipping Drum

5. SHIELDING EVALUATION

The UNC-2901 shipping containers are used for the shipment of oxides of low enriched uranium ($\leq$5 wt.% U-235) in pellet or powder form. Thus, shielding is not a consideration in the design and construction of this shipping container.

6. CRITICALITY SAFETY EVALUATION

6.1 Discussion and Results

This section discusses the demonstration of compliance with the criticality safety requirements of 10 CFR Part 71.

6.1.1 Individual Container - Pellets

The individual container with 16 pellet trays holding a total of 91 Kg of 0.325 inch OD pellets, fully flooded with water in the pellet trays, the inner container, the outer container annulus and reflected, resulted in a Keff of 0.8404 +/- .0050. This loading is lower than the minimum loading, consequently the above multiplication factor is conservative for the designated minimum loading of 104 Kg.

6.1.2 Array of Containers - Pellets

6.1.2.1 Normal Transportation

The hypothetical accident test demonstrated that water cannot enter the inner container. Therefore, the pellets remain dry and moderation is only that provided by the packaging materials. A reflected rectangular array of 512 containers (8x8x8), with each container holding 145 Kg of 0.325 inch OD pellets, was analyzed to have a Keff of 0.72388 +/- .00461. Applying the standard safety factors in accordance with 10CFR71.59 and 10CFR71.61 (5 for Fissile Class II and 2 for Fissile Class III) the allowable number of containers would be:

Fissile Class II	102 containers
Fissile Class III	256 containers

6.1.2.2 Accident Conditions

The hypothetical accident test demonstrated that:

1) Water cannot enter the inner container.
2) The total container remained intact.
3) The inner container is not deformed.

Moderation, therefore, is only provided by the wood blocking and the water between the inner container and the outer shell. For conservatism, however, a maximum reactivity scenario was evaluated in which the inner container was flooded and the space between the inner container and the outer shell was modeled as a void. Additionally, the medium between UNC-2901 shipping containers in a water reflected 6x6x6 array (216 containers) was modeled as a void. The model, therefore, accounts for the maximum interaction of the 216 shipping containers for the hypothethical accident conditions.

The UNC-2901 shipping container will be packaged with 16 pellet trays and incorporate the wood blocking, depicted on Drawing D-5018-2001, Rev. 01, to help minimize the movement of contents. Because of the presence of the wood blocking, the pellets cannot escape from their trays during shipment (see Section 6.1.2.3 for discussion). The maximum Keff under these highly improbable conditions for a loading of 104 Kg of UO_2 pellets of 0.3765 inch OD or less is $\leq$ 0.95 when a pellet size correction effect (0.325" to 0.3765") and twice the KENO-IV standard deviation is added to the KENO-IV derived multiplication factor for 0.325 inch OD pellets (see Section 6.4.2.3 for discussion). Applying the standard safety factors in accordance with 10CFR71.59 and 10CFR71.61 (2 for Fissile Class II and 1 for Fissile Class III), the allowable number of containers are:

Fissile Class II	108
Fissile Class III	216

6.1.2.3 Escape of Pellets from Pellet Trays

The wood blocking used in the packaging for the UNC-2901 shipping container prevents the escape of pellets from the bulk pellet trays. The total height of the aluminum skid, the stack of trays, and the wood slab is 10.575 inches. The inner height of the inner container is 10.75 inches, leaving a nominal gap of 0.175 inch. Since the lip of the tray cover is 0.375 inch, the cover cannot come off and contents will not escape from the tray.

6.1.2.4 Summary

Based on the information presented above, 102 containers can be safely shipped as Fissile Class II and 216 containers can be safely shipped as Fissile Class III. Each UNC-2901 shipping container has an individual Transportation Index of 0.50. Since the Aggregate Transport Index is limited to 50, only 100 UNC-2901 containers will be allowed per transport vehicle.

6.2 UNC-2901 Shipping Container Fuel Loadings Limits

6.2.1 Fuel Pellets

The UNC-2901 will be shipped with a minimum of 16 pellet trays. When less than 16 loaded pellet trays need to be shipped, the 16 tray packaging complement may be made up of dummy trays (fabricated of wood) or empty trays with a wood block insert to preclude the potential for tray collapse during a hypothetical accident scenario. Trays containing pellets will be loaded with a minimum of 6.5 Kg and a maximum of 9.07 Kgs of pellets having a diameter of ≤ 0.3765 inch.

6.3 Model Specifications

The analytical model of the UNC-2901 shipping container was based on Drawings D-5007-8086, Rev. 05 and D-5018-2001, Rev. 01.

6.3.1 Pellet Non-Accident Calculational Model Assumptions

The following assumptions were made for the analysis of fuel pellet shipments:

a. Pellet tray lids do not open.
b. No water enters the inner container.
c. 8x8x8 array of shipping containers surrounded by one foot of water.
d. Full interaction of shipping containers which produced the maximum reactivity:
   - no water between inner container and outer shell of UNC-2901 shipping container.
   - no water between UNC-2901 shipping containers.
e. Sixteen pellet trays are modeled with equal uranium weight per tray.
f. Non-accident dimensions for shipping container were:
   I.D.= 22.5 inches, O.D.= 22.6 inches
g. Density of pellets = 10.25 g-UO_2/cc.
h. Pellet diameter of 0.325 inch.
i. Pellets are assumed to be internally dry.
j. Enrichment of uranium is 5.0 wt % U-235.
k. The analysis of the isolated shipping container assumes each pellet tray holds 5.67 Kgs of pellets and is fully flooded with water. This loading is less than the minimium loading thus assuring a conservative estimate of the multiplication factor for this analysis. The inner container is also assumed to be flooded. In the outer container, the Fiberlite insulation has been replaced with water. The shipping container is reflected by 30 cm of water.

6.3.2 Pellets - Accident Calculational Model Assumptions

The following assumptions were made for the analysis of fuel pellet shipments:

a. Pellet tray lids do not open. As such, pellets do not escape from the trays and are not floating in high water to fuel ratio regions.
b. Inner container is fully flooded with water.
c. 6x6x6 array of shipping containers surrounded by one foot of water.

d. Full interaction of shipping containers which produced the maximum reactivity:
   - no water between inner container and outer shell of UNC-2901 shipping container.
   - no water between UNC-2901 shipping containers.
e. Sixteen pellet trays are modeled with equal uranium weight per tray.
f. Accident dimensions for shipping container were:
   I.D.= 21.0 inches, O.D.= 21.1 inches
g. Density of pellets = 10.25 g-UO2/cc.
h. Pellet diameter of 0.325 inch.
i. Pellets are assumed to be internally dry.
j. Enrichment of uranium is 5.0 wt % U-235.

6.4 Criticality Calculation

6.4.1 Calculational Method

For the fuel pellet analysis the NITAWL code (Ref. 4) was used to generate self-shielded 123-group cross sections from a master AMPX library (Ref. 5). The Dancoff correction supplied as input to NITAWL is based upon the modeled water to fuel ratio inside the pellet trays. The resulting working library was then collapsed into a homogenized 16-group library based on an infinite lattice of uniformly spaced fuel pellets representative of the environment in the pellet tray using XSDRNPM (Ref. 4). XSDRNPM was also used to obtain separate 16-group cross section sets for the structural materials, insulation, and the moderator areas external to the fuel area. Reactivities were calculated using KENO-IV (Ref. 1), a three-dimensional Monte Carlo criticality code.

6.4.2 KENO-IV Results and Input Models

Table 6-1 summarizes the K-effectives for pellet evaluations discussed herein. Sections 6.4.2.1 through 6.4.2.3 below provide further details of the analyses performed for each of the scenarios evaluated.

6.4.2.1 Pellets - Isolated Container

A KENO-IV case was performed for an isolated UNC-2901 shipping container with 16 loaded pellet trays. Each tray contained 5.67 Kg (91 Kg total in container) of 0.325 inch OD pellets for a conservative estimate of the multiplication factor. The pellet trays, the inner container and the space between the inner and outer container were fully flooded with water. The individual container was also reflected with full-density water. The KENO-IV calculated Keff for this scenario is 0.8404 +/- .0050. The KENO-IV input model for this analysis is given in Figure 6.1 and the input parameters are provided in Table 6-2.

6.4.2.2 Pellets - Non-Accident Geometry

The KENO-IV calulated Keff for the 8x8x8 array of UNC-2901 shipping containers, each containing 145 Kg of 0.325 inch OD pellets, is 0.72388 +/- .00461. The KENO-IV input data for this scenario is given in Table 6-3.

6.4.2.3 Pellets - Accident Geometry

In practice, the UNC-2901 shipping container is loaded with approximately 127 Kg of pellets. KENO-IV cases were performed with 145, 127, 109, 98 and 91 Kg of 0.325 inch OD pellets per shipping container in a 6x6x6 array of accident geometry containers. The following table summarizes the KENO-IV results:

Total Weight of Pellets, Kgs.	Avg. Weight per tray, Kgs	V_{H2O}/V_{UO2}	K-eff
145.1	9.07	0.740	0.90854 +/- .00475
127.0	7.94	0.989	0.92661 +/- .00363
108.8	6.80	1.320	0.93387 +/- .00460
97.6	6.10	1.730	0.94030 +/- .00438
90.7	5.67	1.784	0.94391 +/- .00449

The KENO-IV input data for the 98 Kg scenario is given in Table 6-4.

Section 6.6 provides a discussion of the effect of pellet diameter and volume ratio of water to oxide on reactivity. It is concluded that at volume ratios below approximately 2.5, reactivity increases with pellet diameter. Since the KENO-IV analyses presented herein are done at a pellet diameter of 0.325 inch and the highest water to oxide volume ratio is less than 2.5, it may be concluded that these analyses are conservative for pellet diameters $\leq$ 0.325 inch.

For pellet diameters larger than 0.325 inch, reactivity is expected to increase with pellet diameter when the water to oxide volume ratio is less than 2.5. To estimate the reactivity effect when 0.3765 inch OD pellets are substitued for 0.325 inch OD pellets in the pellet trays, for a given weight loading per tray, the data of Figure 6.2 were employed. The reactivity increase was computed by taking the fractional increase in infinite multiplication factor times the KENO-IV derived effective multiplication factor. For conservatism, the data for a water to oxide volume ratio of 1.320 was used since the limiting case of interest (minimum Kg UO_2 per tray) has a volume ratio between 1.32 and 1.784. The fractional increase in infinite multiplication factor was taken to be (1.470-1.464)/1.464 in going from 0.325 inch to 0.3765 inch OD pellets. It was thus concluded that the reactivity adjustment was the above fractional increase in infinite multiplication factor times the effective multiplication factor for 6.1 Kg UO_2 per tray, or 0.00385.

To estimate the minimum loading per tray required so that the sum of the KENO-IV calculated multiplication factor plus twice the KENO-IV standard deviation plus the pellet size correction is $\leq$ 0.95, the following data were used:

Avg Weight per Tray	Adjusted K-eff
6.80 Kg	0.93387 + 2(0.00460) + 0.00385 = 0.94692
6.10 Kg	0.94030 + 2(0.00438) + 0.00385 = 0.95291

The limiting weight per tray based on a target value for Keff of 0.95 is 6.44 Kg using linear interpolation. This value was rounded up to 6.5 Kg UO_2 per tray or 104 Kg UO_2 for 16 trays.

Because of the magnitude of the pellet size correction factor as compared to the magnitude of Keff, no pellet diameter adjustments were made to the calculations reported above in Sections 6.4.2.1 and 6.4.2.2.

6.5 Code Validation

6.5.1 Homogeneous UO_2 - Moderator Mixtures

Validation of a calculational scheme employing the KENO-IV code (Reference 1) and the sixteen group Hansen-Roach cross section set distributed under the SCALE code system (Reference 2) is contained in Reference 3. To ascertain whether the conclusions of the latter reference are applicable to analyses carried out at Combustion Engineering, Inc., the following comparisons were made.

1) The Hansen-Roach cross section library at Combustion Engineering, Inc. was verified as being identical to that distributed under SCALE, and

2) Eight of the sample problems distributed with the code were run for purposes of comparing the calculated eigenvalues with those obtained by ORNL.

Table 6.5 summarizes the eigenvalue comparison; it is noted that the eigenvalues agree within the stated statistical deviation. Thus, it may be concluded that the conclusions of Reference 3 concerning bias and deviation are applicable to homogeneous analyses performed by Combustion Engineering, Inc.

6.5.2 Heterogeneous UO_2 - Moderator Mixtures

Heterogeneous UO_2 - moderator lattices for fuel shipping containers are analyzed with the KENO-IV code and a sixteen group library generated for the lattice of interest. The latter library is prepared with the NITAWL and XSDRNPM codes (Reference 4). Lattice dependent Dancoff factors are calculated for input to NITAWL to generate self-shielded 123 group cross sections from the super - XSDRN library (Reference 5). This library is employed with XSDRNPM to calculate 123 group constants which are collapsed to sixteen group flux weighted fuel cell averaged cross sections. XSDRNPM is also used to obtain separate 16 group cross section sets for the structural materials, insulation, and the moderator areas external to the UO_2 regions.

Validation of this calculational scheme is based on analysis of two sets of experiments: (1) the dissolution and storage experiments carried out by the Department of Nuclear Safety of the French Atomic Energy Commission (Reference 6), and (2) the consolidated fuel rod experiments carried out at the Babcock and Wilcox Facility under the auspices of the U.S. Department of Energy (Reference 7).

Emphasis was placed on the analysis of the storage aspect of the French experiments. In these experiments, the reactivity effects of replacing water in the inter-fuel assembly gap by air, expanded polystyrene $((C_8H_8)n)$, polyethylene powder $((CH_2)n)$, and polyethylene balls were examined for gap thickness of 2.5, 5.0, and 10.0 cm. Application of the calculational scheme outlined above resulted in the KENO-IV results noted in Table 6.6.

The consolidated fuel rod experiments covered five core types. The first three employed a triangular spacing of the close pack fuel rods within a storage module; differences between the three cores were the nominal intermodule spacing (1.78 to 3.81 cm). The fourth core employed close packed fuel rods in a square pitch while the fifth core employed an open square pitch. All cores were critical at full water height using soluble boron as the variable.

The following tabulation summarizes the KENO-IV multiplication factors for the first three cores.

Core No.	KENO-IV KEFF
I	1.008 ± 0.002
II	0.996 ± 0.002
III	0.978 ± 0.002

The above results demonstrate that the calculational scheme for heterogeneous lattices based in the NITAWL - XSDRNPM - KENO-IV computer codes does give acceptable agreement with experiment for use in criticality evaluations. The systematics of the deviations between calculation and experiment indicate the model to be conservative for the French experiments. In the case of the fuel consolidation experiments the same trend is observed in the calculational results as reported in Reference 7.

6.6 Pellet Size Reactivity Effects Sensitivity Study

The purpose of this section is to explore the reactivity effects of pellet size. A range of pellet sizes are employed in the various PWR and BWR fuel rods. In addition, there are a range of dimensions associated with hard scrap resulting from broken pellets. Since the KENO-IV analyses for the 4x2x2 array of bulk pellet trays was done for 0.325 inch diameter pellets, it is of interest to examine the consequences of larger or smaller pellet/particle dimensions. Two types of data are employed, critical mass data versus pellet size, and infinite multiplication factor data versus pellet size and volume ratio of water to UO_2.

The critical mass data is extracted from Reference 8 since data are tabulated in this reference for pellet sizes varying from 0.05 to 0.60 inch in diameter. Figure 6.3 shows plots of critical mass in Kg U-235 versus volume ratio of water to UO_2 for five pellet diameters in addition to that for UO_2 powder (i.e., 0" pellet diameter). In addition, the variation of migration area, M^2, is shown versus water to UO_2 volume ratio to show that M^2 is not a strongly varying quantity. Thus, it can be expected that these data or variation in critical mass can be directly related to changes in reactivity for varying pellet diameter when other variables remain unchanged.

The variation of critical mass with volume ratio of water to UO_2 for the differing pellet diameters shows a markedly different behavior at volume ratios below approximately 2.5. In this regime, the critical mass decreases with increasing pellet diameter; thus, it is expected that at a fixed volume ratio, increasing the pellet size leads to an increase in reactivity. Consequently, for a fixed volume container, a given mass loading limit results in a given limit in the water to fuel ratio, and at this loading limit an increase in pellet diameter leads to an increase in reactivity providing the volume ratio is below approximately 2.5.

Conversely, at the higher water to fuel ratios and especially at the point of optimum moderation for a given pellet diameter, the critical mass decreases with decreasing pellet size to a minimum in the range of 0.05 to 0.1 inch pellet diameter depending how over moderated the lattice becomes. For the bulk pellet trays employed in the 4x2x2 packaging arrays, the UO_2 loading per tray varies from 5.67 to 9.07 Kg; the corresponding range of water to UO_2 volume ratios is 1.78 to 0.74. Thus, the cases of interest fall below 2.5 in water to UO_2 volume ratio.

Figure 6.2 shows plots of the infinite multiplication factor versus pellet diameter for volume ratios between 0.740 and 1.784. The variation of the infinite multiplication factor is as deduced from the variation of critical mass with pellet diameter from Figure 6.3 (viz. the infinite multiplication factor is increasing with pellet diameter for these very dry mixtures of pellets and water).

6.7 References

1. L. M. Petrie and N. F. Cross, "KENO-IV, An Improved MONTE CARLO Criticality Program," ORNL-2938, November, 1975.

2. "SCALE: A Modular Code System for Performing Standardized Computer Analysis for Licensing Evaluation - Book II", NUREG/CR-0200.

3. G. R. Handley and C. M. Hopper, "Validation of the "KENO" Code for Nuclear Criticality Safety Calculations of Moderated, Low-Enriched Uranium Systems", Y-1948, June 13, 1974.

4. N. M. Green, et al, "AMPX: A Modular Code System for Generating Coupled Multigroup Neutron-Gamma Libraries from ENDF/B", ORNL/TM-3706, March 1976.

5. W. R. Cable, "123 Group Neutron Cross Section Data Generated from ENDF/B-II Data for use in the XSDRN Discrete Ordinates Spectral Averaging Code", DLC-16, Radiation Shielding Information Center, 1971.

6. J. C. Manarache, et al, "Dissolution and Storage Experiment With 4.75 w/o U-235 Enriched UO_2 Rods", Nuclear Technology, Vol. 50, pg 148, September 1980.

7. G. S. Hooper, et al, "Critical Experiments Supporting Storage of Tightly Packaged Configurations of Spent Fuel Rods," BAW-1645-4, November, 1981.

8. H. K. Clark, "Critical and Safe Masses and Dimensions of Lattices of U and UO_2 Rods in Water", DP-1014 Savannah River Laboratory, February 1966.

TABLE 6-1

SUMMARY OF CRITICALITY EVALUATION

KENO IV RESULTS FOR THE UNC-2901 SHIPPING CONTAINER - UO_2 PELLETS (0.325" OD)

Array	Geometry Dev. No. of Trays	UO_2 Weight Kgs/Container	K-Effective	(+ or -)
8x8x8	Non-Accident	145	0.7238	0.0046
6x6x6	Accident	145	0.9085	0.0048
6x6x6	Accident	127	0.9266	0.0036
6x6x6	Accident	109	0.9339	0.0046
6x6x6	Accident	98	0.9403	0.0044
6x6x6	Accident	91	0.9439	0.0045

Table 6-2
KENO-IV Input
Pellets (0.325" OD)
Isolated Container - 91 Kgs

```
     5.00    50      500      3      16
       15    29        6     29      13
        1     6        6      6     -29
        1     0     1010     00       1
        1     1        0      0       0
       00     0        0
  0.0   0.0   0.0   0.0   0.0   0.0
  1  -92235   3.541897E-4
  1   92238   6.644599E-3
  1    8016   3.378829E-2
  1    1001   3.958142E-2
  1   26012   3.232260E-5
  1  224000   1.679824E-3
  1  225055   1.766620E-4
  1  226000   6.156296E-3
  1  228000   6.612613E-4
  1  214028   1.727761E-4
  2   26012   3.1691E-4
  2  224000   1.647E-2
  2  225055   1.7321E-3
  2  226000   6.036E-2
  2  228000   6.4834E-3
  2  214028   1.694E-3
  3   38016   3.342984-2
  3   31001   6.685969-2
  4   58016   9.852100-3
  4   66012   1.612600-2
  4   51001   2.812100-2
  5   46012   3.921000-3
  5  426000   8.349100-2
  6   26012   3.3435E-4
  6  224000   1.7376E-2
  6  225055   1.8274E-3
  6  226000   6.3682E-2
  6  228000   6.8402E-3
  6  214028   1.7872E-3
BOX TYPE  1
CUBOID     1   13.3350  -13.3350  52.0700    0.0000   7.71525 -13.11275 16*0.5
CUBOID     3   13.3350  -13.3350  59.6900    0.0000   7.71525 -13.11275 16*0.5
CUBOID     3   13.3350  -13.3350  59.6900    0.0000   7.71525 -13.43025 16*0.5
CUBOID     3   13.3350  -13.3350  59.6900   -5.0800   7.71525 -13.43025 16*0.5
CUBOID     4   13.3350  -13.3350  59.6900   -5.0800  13.43025 -13.43025 16*0.5
CUBOID     3   13.3350  -13.3350  60.9600   -5.0800  13.43025 -13.43025 16*0.5
CUBOID     4   13.3350  -13.3350  60.9600  -13.9700  13.43025 -13.43025 16*0.5
CUBOID     3   13.6525  -13.6525 .60.9600  -13.9700  13.65250 -13.65250 16*0.5
CUBOID     5   13.85087 -13.85087 62.2300  -14.16837 13.85087 -13.85087 16*0.5
YCYLINDER  3   26.6700   67.3100 -22.61895                              16*0.5
YCYLINDER  5   26.7970   67.46875 -22.74595                             16*0.5
YCYLINDER  3   57.2770   97.94875 -53.22595                             16*0.5
CUBOID     0   57.2770  -57.2770  97.94875 -53.22595 57.27700 -57.27700 16*0.5
END KENO
```

UNC-2901 SHIPPING CONTAINER

Table 6-3
KENO-IV Input
Pellets (0.325" OD)
8x8x8 Array - 145 Kgs
Non-Accident Geometry

```
  10.00     50      500       3        16
      6     11        5      11        14
      1      8        8       8        11
      1      0     1010      00         1
      1      1        0       0         0
     00      0        0
  0.0  0.0  0.0  0.0  0.0  0.0
  1  -92505   4.719479E-5
  1  -92506   5.195087E-4
  1   92803   9.708311E-3
  1   92804   9.230486E-4
  1    8100   2.239613E-2
  2     200   1.0
  3     502   1.0
  4    8100   9.852100-3
  4    6100   1.612600-2
  4    1102   2.812100-2
  5     100   1.0
BOX TYPE  1
CUBOID     1    13.3350  -13.3350  52.0700    0.0000    7.71525 -13.11275 16*0.5
CUBOID     0    13.3350  -13.3350  59.6900    0.0000    7.71525 -13.11275 16*0.5
CUBOID     0    13.3350  -13.3350  59.6900    0.0000    7.71525 -13.43025 16*0.5
CUBOID     0    13.3350  -13.3350  59.6900   -5.0800    7.71525 -13.43025 16*0.5
CUBOID     4    13.3350  -13.3350  59.6900   -5.0800   13.43025 -13.43025 16*0.5
CUBOID     0    13.3350  -13.3350  60.9600   -5.0800   13.43025 -13.43025 16*0.5
CUBOID     4    13.3350  -13.3350  60.9600  -13.9700   13.43025 -13.43025 16*0.5
CUBOID     0    13.6525  -13.6525  60.9600  -13.9700   13.65250 -13.65250 16*0.5
CUBOID     5    13.85087 -13.85087 62.2300  -14.16837 13.85087 -13.85087 16*0.5
YCYLINDER  0    28.5750   67.3100  -22.61895                              16*0.5
YCYLINDER  5    28.7020   67.46875 -22.74595                              16*0.5
CUBOID     0    28.7020  -28.7020  67.46875 -22.74595 28.7020  -28.7020   16*0.5
CORE BDY   0   459.2320    0.0000 721.7176    0.0000 459.2320    0.0000   16*0.5
CUBOID     3   489.7120  -30.4800 752.1976  -30.4800 489.7120  -30.4800   16*0.5
END KENO
```

Table 6-4
KENO-IV Input
Pellets (0.325" OD)
6x6x6 Array - 98 Kg
Accident Geometry

```
   5.00     50     500     3      15
    15      29       6    29      14
     1       6       6     6     -29
     1       0    1010    00       1
     1       1       0     0       0
    30       0       0
 0.0  0.0  0.0  0.0  0.0  0.0
 1  -92235   3.310509E-4
 1   92238   7.148507E-3
 1    8016   3.407407E-2
 1    1001   3.302985E-2
 1   26012   3.232250E-5
 1  224000   1.679824E-3
 1  225055   1.766620E-4
 1  226000   6.156296E-3
 1  228000   6.612613E-4
 1  214028   1.727751E-4
 2   26012   3.1591E-4
 2  224000   1.647E-2
 2  225055   1.7321E-3
 2  226000   6.036E-2
 2  228000   6.4834E-3
 2  214028   1.694E-3
 3   38016   3.342984-2
 3   31001   6.685969-2
 4   58016   9.352100-3
 4   56012   1.612600-2
 4   51001   2.812100-2
 5   46012   3.921000-3
 5  426000   8.349100-2
 6   26012   3.3435E-4
 6  224000   1.7376E-2
 6  225055   1.8274E-3
 6  226000   6.3682E-2
 6  228000   6.8402E-3
 6  214028   1.7872E-3
BOX TYPE  1
CUBOID     1    13.3350  -13.3350  52.0700    0.0000   7.71525 -13.11275 16*0.5
CUBOID     3    13.3350  -13.3350  59.6900    0.0000   7.71525 -13.11275 16*0.5
CUBOID     0    13.3350  -13.3350  59.6900    0.0000   7.71525 -13.43025 16*0.5
CUBOID     3    13.3350  -13.3350  59.6900   -5.0800   7.71525 -13.43025 16*0.5
CUBOID     4    13.3350  -13.3350  59.6900   -5.0800  13.43025 -13.43025 16*0.5
CUBOID     3    13.3350  -13.3350  60.9600   -5.0800  13.43025 -13.43025 16*0.5
CUBOID     4    13.3350  -13.3350  60.9600  -13.9700  13.43025 -13.43025 16*0.5
CUBOID     3    13.6525  -13.6525  60.9600  -13.9700  13.65250 -13.65250 16*0.5
CUBOID     5    13.85087 -13.85087 62.2300  -14.16837 13.85087 -13.85087 16*0.5
YCYLINDER  0   26.6700   67.3100  -22.61895                              16*0.5
YCYLINDER  5   26.7970   67.46875 -22.74595                              16*0.5
CUBOID     0   26.7970  -26.7970  67.46875 -22.74595 26.7970 -26.7970   16*0.5
CORE BDY   0  321.5640    0.0000 541.2882    0.0000 321.5640   0.0000   16*0.5
CUBOID     3  352.0440  -30.4800 571.7682  -30.4800 352.0440 -30.4800   16*0.5
END KENO
```

Table 6.5

Comparison of KENO-IV Calculated Eigenvalues for Sample Problems

Problem Number	Eigenvalues C-E	Eigenvalues ORNL
1	1.00387 +/- .00448	1.00569 +/- .00446
2	0.99733 +/- .00426	1.00099 +/- .00442
10	0.74638 +/- .00446	0.75215 +/- .00436
11	0.99846 +/- .00487	0.99380 +/- .00515
12	0.92957 +/- .00449	0.93089 +/- .00419
13	2.26645 +/- .00603	2.26172 +/- .00566
14	0.98487 +/- .00625	0.98060 +/- .00558
19	0.99726 + - .00452	1.00014 +/- .00567

UNC-2901 SHIPPING CONTAINER

Table 6.6

Results of Experiements and Benchmark Calculations in the
Case of Interposition of Hydrogeneous Compounds Between Four Assemblies
of 18 x 18 (4.75%) UO_2 Rods at 13.5 mm Square Pitch

Experiemental Results

* Δ (cm)		Compounds: Nature	Compounds: Density (g/cm^3)	Compounds: Concentration Hydrogen (g/cm^3)	Water Critical Height (mm)	Calculated Results KENO-IV
0	1.	Water	1.0	0.1119	238 ± 0.6	-
	2.	Box + air	0	0	290.3 ± 0.9	0.99641 ± 0.00407
	3.	Box + $(C_8H_8)n$	0.0323	0.0025	286.1 ± 0.8	0.99913 ± 0.00384
2.5	4.	Box powder $(CH_2)n$	0.2879	0.0414	259.8 ± 0.6	1.01567 ± 0.00378
5.0	5.	Box + balls $(CH_2)n$	0.5540	0.0800	255.4 ± 0.6	-
	6.	Box + water	1.0	0.1119	256.8 ± 0.7	1.02362 ± 0.00362
	7.	Water	1.0	0.1119	244.8 ± 0.6	0.99775 ± 0.00391
	8.	Box + air	0	0	344.8 ± 0.7	1.00412 ± 0.00422
	9.	Box + $(C_8H_8)n$	0.0262	0.0020	343.9 ± 0.8	1.00647 ± 0.00421
5.0	10.	Box + powder $(CH_2)n$	0.3335	0.0480	301.6 ± 0.6	-
	11.	Box + balls $(CH_2)n$	0.5796	0.0833	307.3 ± 0.8	-
	12.	Box + water	1.0	0.1119	238.3 ± 0.3	-
	13.	Water	1.0	0.1119	314.7 ± 0.6	-
	14.	Box + air	0	0	460.8 ± 0.7	1.00117 ± 0.00396
	15.	Box + $(C_8H_8)n$	0.0288	0.0022	456.2 ± 0.8	1.00748 ± 0.03378
10.0	16.	Box + powder $(CH_2)n$	0.3216	0.0464	420.5 ± 0.6	-
	17.	Box + balls $(CH_2)n$	0.5680	0.0816	499.4 ± 0.6	-
	18.	Box + water	1.0	0.1119	641.2 ± 0.9	-
	19.	Water	1.0	0.1119	643.4 ± 0.8	-

* The symbol Δ is the value of the gap width between the assemblies, thus it is the value of cross-shaped box width. The actual thickness of hydrogeneous compounds is Δ (H) = Δ 0.6 cm.

UNC-2901 SHIPPING CONTAINER

FIGURE 6.1
KENO MODEL FOR UNC-2901 SHIPPING CONTAINER

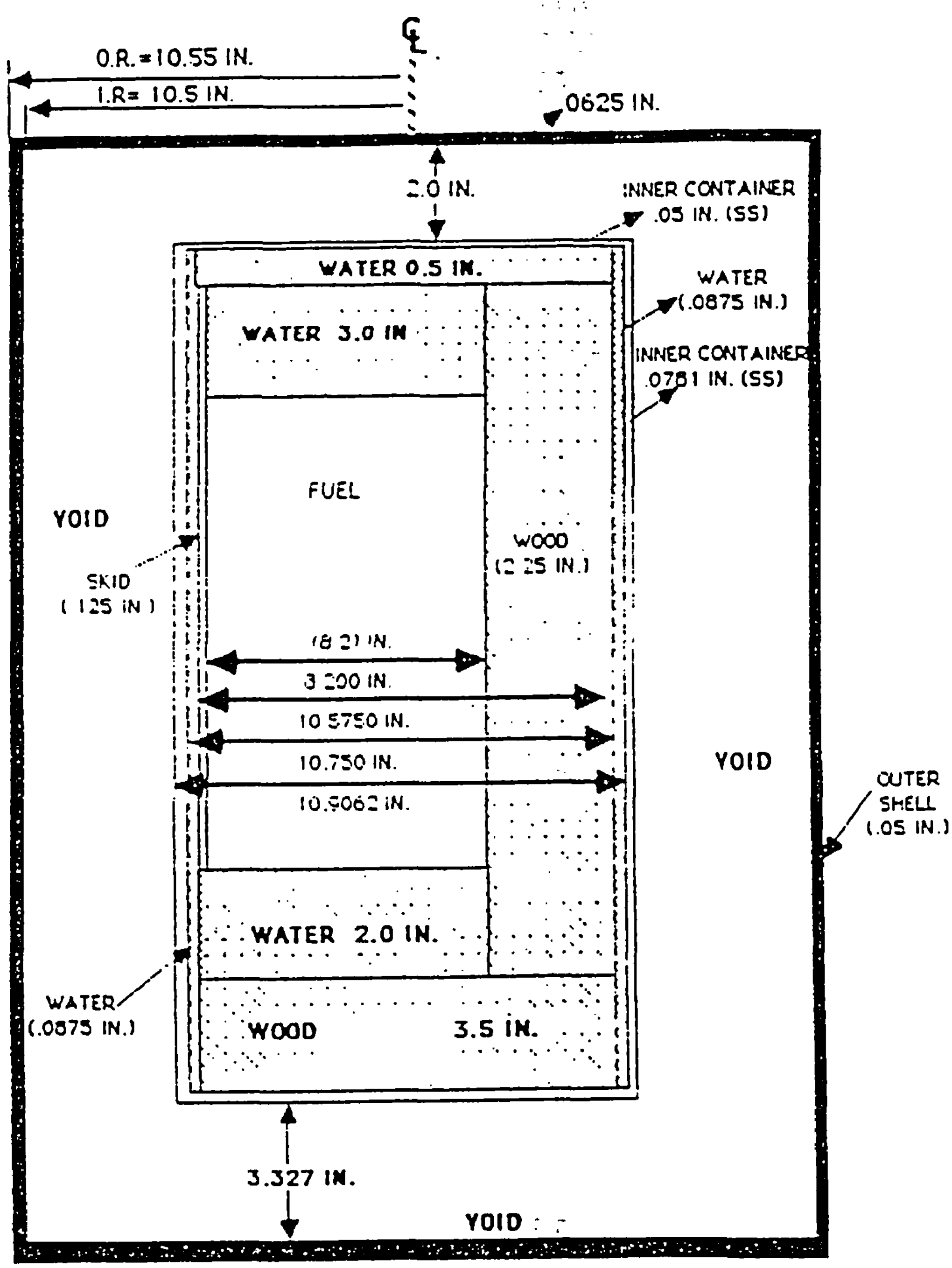
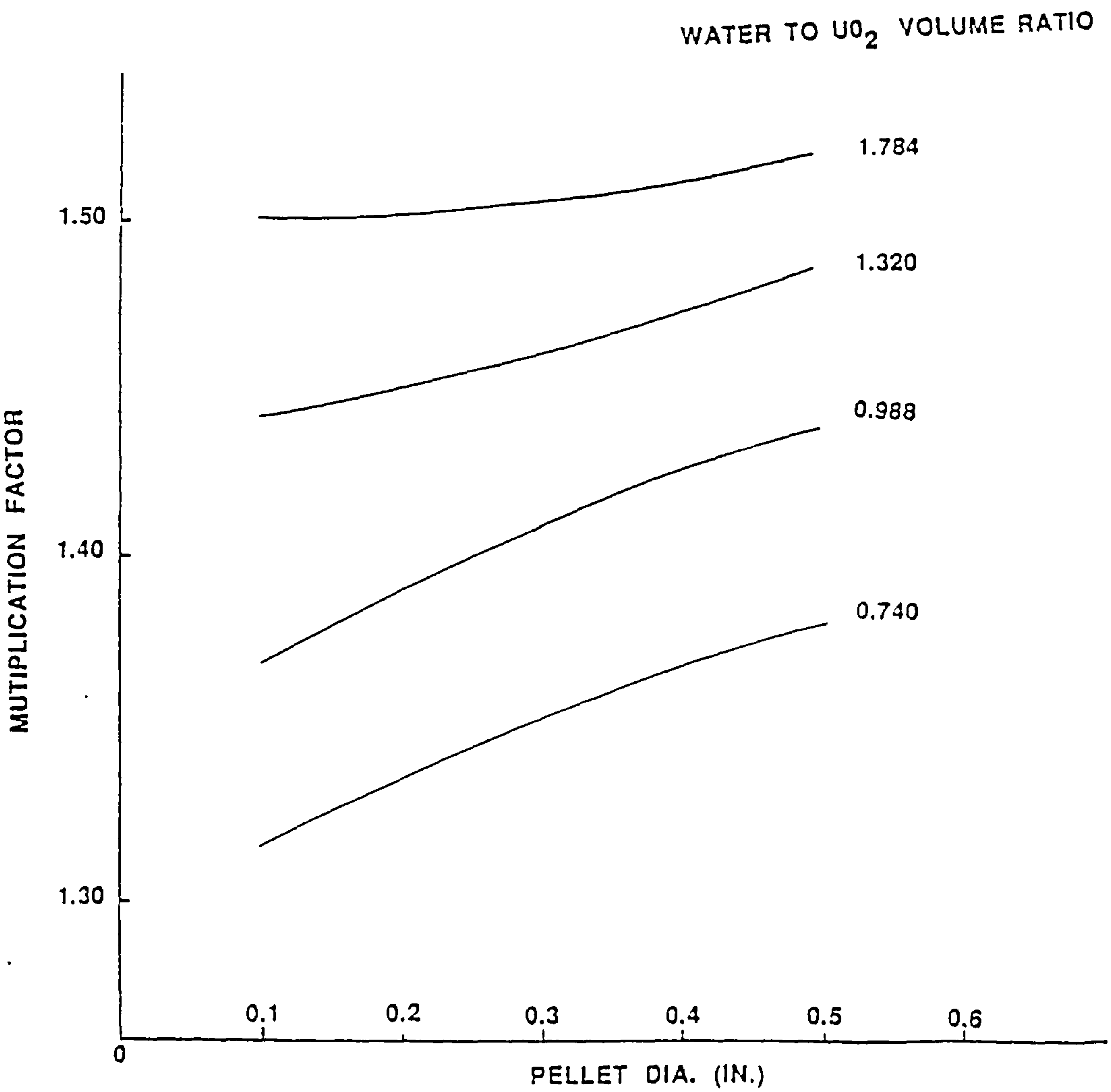
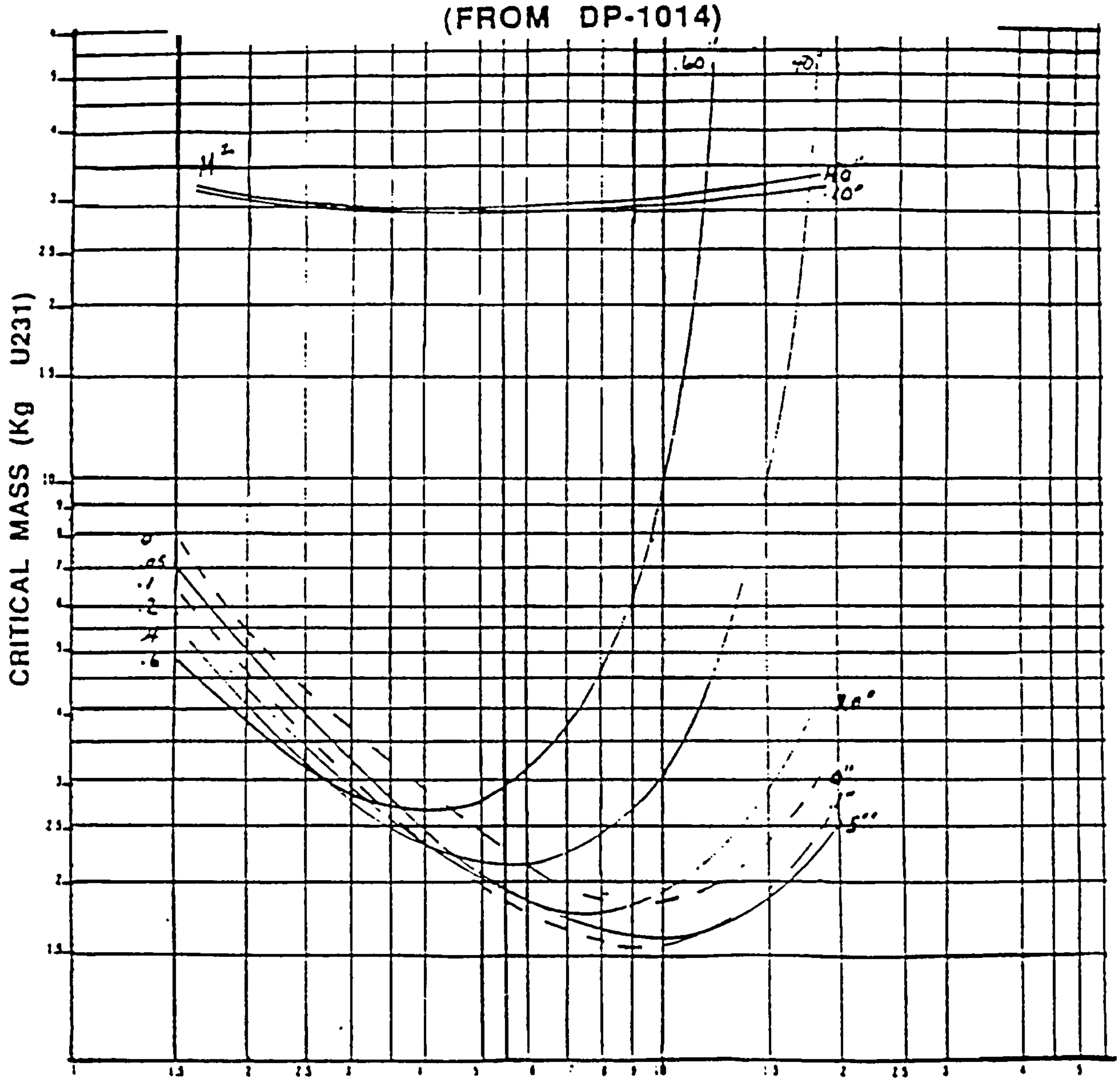


FIGURE 6.2
INFINITE MULTIPLICATION FACTOR
VERSUS PELLET DIAMETER FOR WATER
TO UO_2 VOLUME RATIOS



UNC-2901 SHIPPING CONTAINER

FIGURE 6.3
REFLECTED CRITICAL MASS VERSUS WATER TO UO_2 VOLUME RATIO FOR 5 w/o UO_2 PELLETS OF VARIOUS DIAMETERS
(FROM DP-1014)



7. OPERATING PROCEDURES

Loading and unloading of the package are relatively simple, straight forward operations, however, detailed procedures and check lists are followed. UO_2 pellets and reject pellets are shipped in the UNC-2901 shipping container. The requirements for loading and unloading the containers are described below.

7.1 Procedures for Loading the Package

Specific written operating procedures are followed. The procedures detail inspection requirements and acceptance criteria and require notification of line supervision when acceptance criteria are not met. Line supervision will notify the affected Line Manager(s) and the Plant Manager, as appropriate. The procedures require the following as a minimum:

1. Instructions for packaging of the specific items in the manner described in the approved drawings.
2. The UNC-2901 shipping container shall be loaded in accordance with the loading limits determined by the criticality analyses (see Section 6.2). For pellet shipments, when less than 16 loaded bulk pellet trays need to be shipped, the 16 tray packaging complement may be made up of dummy trays (fabricated of wood) or empty trays with a wood block insert to preclude the potential for tray collapse during a hypothetical accident scenario.
3. Inspection for damage prior to loading the container.
4. Inspection during loading and completion of a check list to assure the following internal items are properly installed:
   a. 14" square 1/2" thick steel flange.
   b. 14" square 1/8" thick full face gasket.
   c. 12 1/2-13 NC Hex Head Bolts which hold the flange and gasket in place.
   d. The one piece insert which includes a 22" diameter plywood piece, 22" diameter 1/8" thick ceramic sheet gasket, and a .032" thick aluminum cover.
   e. Wood spacer(s), as required.

5. Inspection of each inner container for:

   a. Soundness of container.
   b. Proper closure.
   c. Proper sealing.
   d. Proper net weight of uranium oxide.
   e. Other special requirements as appropriate.

6. Inspection after loading and completion of a checklist to ensure that the following external items are properly installed:

   a. 16 gage steel drum lid.
   b. 12 gage steel drum lid ring clamp.
   c. Ring clamp bolt.
   d. Tamper proof seal.
   e. Proper labeling.

7. Inspection of containers for removable contamination.

7.2 Procedures for Unloading the Package

Specific written operating procedures are followed. The procedures detail inspection requirements and acceptance criteria and require notification of line supervision when acceptance criteria are not met. Line supervision will notify the affected Line Manager(s) and the Plant Manager, as appropriate. The procedures require the following as a minimum:

1. Inspection prior to unloading the package for:

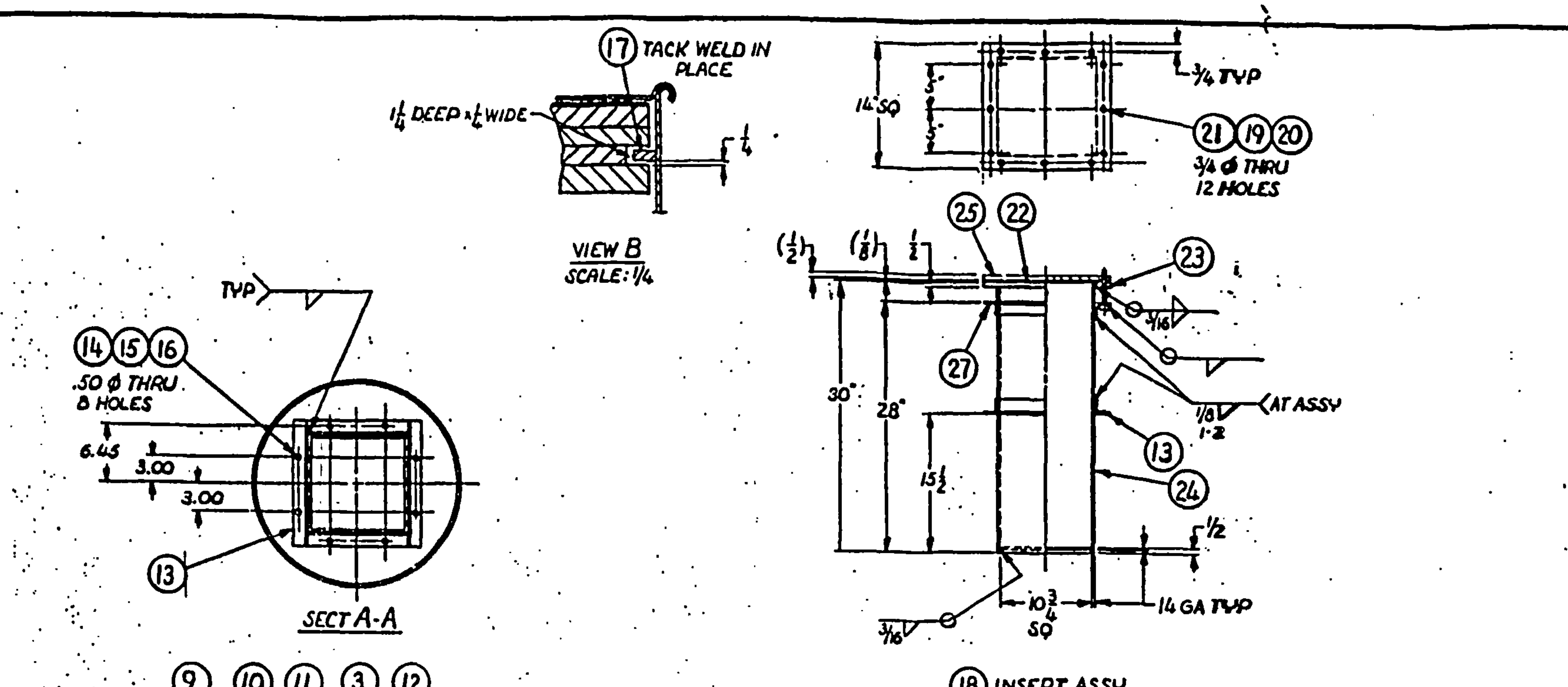
   a. Shipping or handling damage.
   b. Tamper proof seal.
   c. Removable contamination (smear).
   d. Labeling.

2. Instructions for unpackaging.

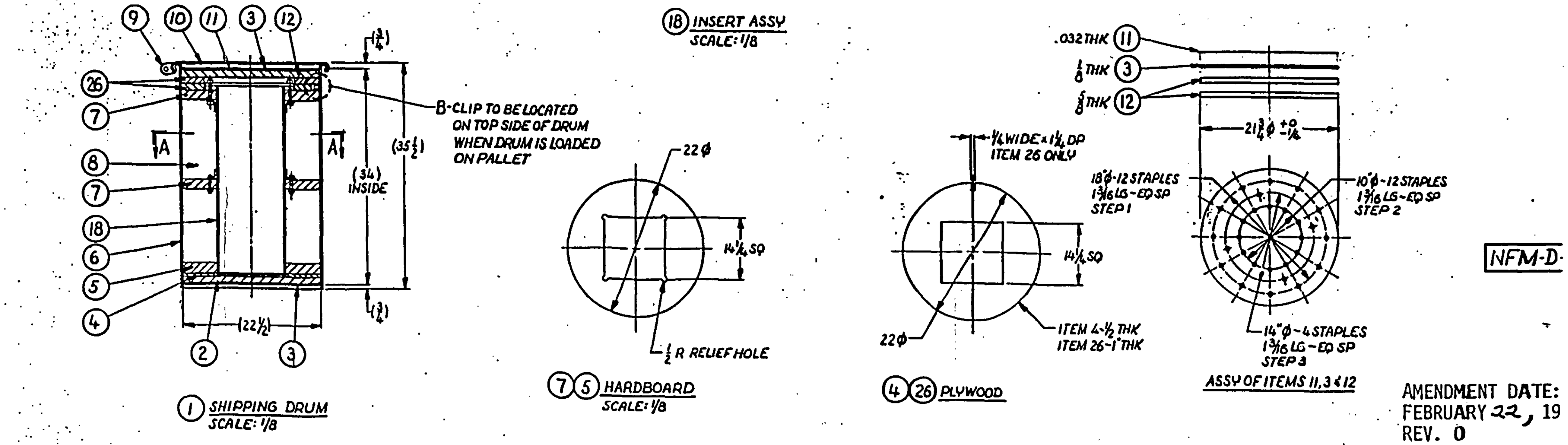
3. Inspection of each inner container for:

   a. Shipping damage

   b. Gross weight of each inner container for comparison to suppliers weight.



GROUP NO. & QUANTITY 6	5	4	3	2	1	ITEM NO.	NAME	PIECE NO.	MATERIAL	
					X	1	SHIPPING DRUM	NFM-D-4540-1		
					1	2	PLYWOOD	-2	PLYWOOD	1"TH
					2	3	CERAMIC SHEET	-3	[illegible]	[illegible]
					1	4	PLYWOOD	-4	PLYWOOD	½ TH
					1	5	HARDBOARD	-5	[illegible]	1½ TH
					1	6	SHIPPING DRUM	-6	STL	[illegible]
					2	7	HARDBOARD	-7	[illegible]	1½ TH
					[illegible]	8	THERMAL INSULATION	-8		[illegible]
					1	9	CLAMP RING	-9	STL	[illegible]
					1	10	DRUM LID ~12GA	-10	STL	[illegible]
					1	11	COVER	-11	ALUM	.032
					2	12	PLYWOOD	-12	PLYWOOD	5/8 TH
					[illegible]	13	ANGLE	-13	STL	1½ x
					8	14	HEX HD BOLT	-14	STL	5/16-18
					8	15	HEX NUT	-15	STL	5/16-1
					16	16	WASHER	-16	STL	5/16
					1	17	CLIP	-17	C.S.	1/8 x 4
				X	1	18	INSERT ASSY	-18		
				12		19	HEX HD BOLT	-19	STL	½-13
				12		20	HEX NUT	-20	STL	½-13
				12		21	WASHER	-21	STL	½
				1		22	GASKET	-22		[illegible]
				1		23	FLANGE	-23	STL	½ x 1
				[illegible]		24	INSERT	-24	STL	14GA
				1		25	COVER	-25	STL	½ x 1
					2	26	PLYWOOD	-26	PLYWOOD	1" THK
					[illegible]	27	ANGLE	-27	STL	1½ x



AMENDMENT DATE:
FEBRUARY 22, 19
REV. 0
PAGE 1-7

UNLESS OTHERWISE SPECIFIED			
DIMENSIONING & TOLERANCING PER ANSI Y14.5 1973			
DIMENSIONS APPLY AT 68°F (20°C)			
DO NOT SCALE DRAWING			
DIMENSIONS	UNDER 6	6-18	OVER 18
DECIMAL	±.005	±.008	±.010
FRACTION	±1/64	±1/32	±1/16
BREAK CORNERS 1/64 APPROX. R OR CHAM — FILLETS 1/64 TO 1/32 R			
FINISH ✓ AA125 MICRO IN.			
ANGLES ± 0°-30'	CHAM ± 5°		

C-E POWER SYSTEMS
COMBUSTION ENGINEERING INC
NUCLEAR POWER SYSTEMS

CUSTOMER: NUCLEAR FUELS MANUFACTURING WINDSOR

NEXT ASSY
SUPERSEDES
JOB NO. 776219
COMPONENT CODE
SCALE NOTED

DRAWN BY MASLOSKI
CHECKED
APPROVALS

TITLE: UNC 29
SHIPPING

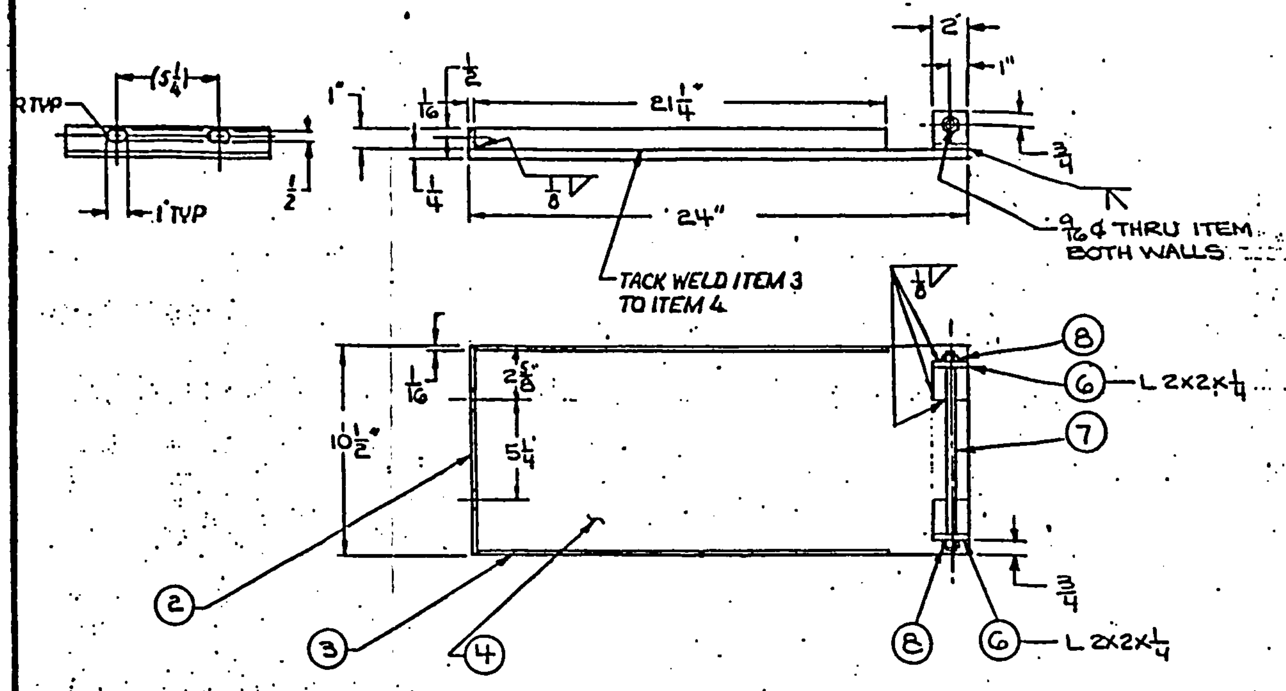
DWG. NO. NFM-D-45
SHEET OF

8 7 6 5 4 3 2 1

BILL OF MATERIALS

QUANTITIES ARE FOR

GROUP NO. & QUANTITY 6	5	4	3	2	1	ITEM NO.	NAME	PIECE NO.	MATERIAL	REMARKS
					X	1	PELLET TRAY HOLDER	NFM-D-4263-1	6061	ALUM.
					1	2	END RAIL	NFM-D-4263-2	6061	ALUM.
					2	3	SIDE RAIL	NFM-D-4263-3	6061	ALUM.
					1	4	BASE	NFM-D-4263-4	6061	ALUM.
						5				
					2	6	ANGLE	NFM-D-4263-6	6061 ALUM	L2X2X1/4X2LG
					1	7	THREADED ROD	NFM-D-4263-7	C.S	1/2-13UNC-2AX10"LG
					2	8	HEX HD NUT	NFM-D-4263-8	C.S	1/2-13UNC-2B



① PELLET TRAY HOLDER
SCALE: 1/4

NFM-D-4263
02

AMENDMENT DATE:
FEBRUARY 22, 1990.
REV. 0
PAGE 1-6

REV.	DESCRIPTION	BY & DATE	CHK & DATE	ENG. APPD	PROJ. APPD
01	1-BM & FACE OF DWG DELETED ITEM 5 & ADDED ITEMS 6,7 & 8 & RELATED DIMS PER REQ REQ # 87-650				
02	1-CH'G'D 1/2 ⌀ HOLE TO 1/2 W × 1 1/2 LG SLOTS 2-WELDS WERE 1/16 3-ADDED TACK WELD NOTE PER REV REQ 88-799				

UNLESS OTHERWISE SPECIFIED
DIMENSIONING & TOLERANCING PER ANSI Y14.5 1973
DIMENSIONS APPLY AT 68°F (20°C)
DO NOT SCALE DRAWING

DIMENSIONS	UNDER 6	6 - 18	OVER 18
DECIMAL	± .005	± .005	± .010
FRACTION	± 1/64	± 1/32	± 1/16

BREAK CORNERS 1/64 APPROX. R OR CHAM — FILLETS 1/64 TO 1/32 R
FINISH (✓) AA125 MICRO IN.
ANGLES ± 0° - 30' CHAM ± 5°

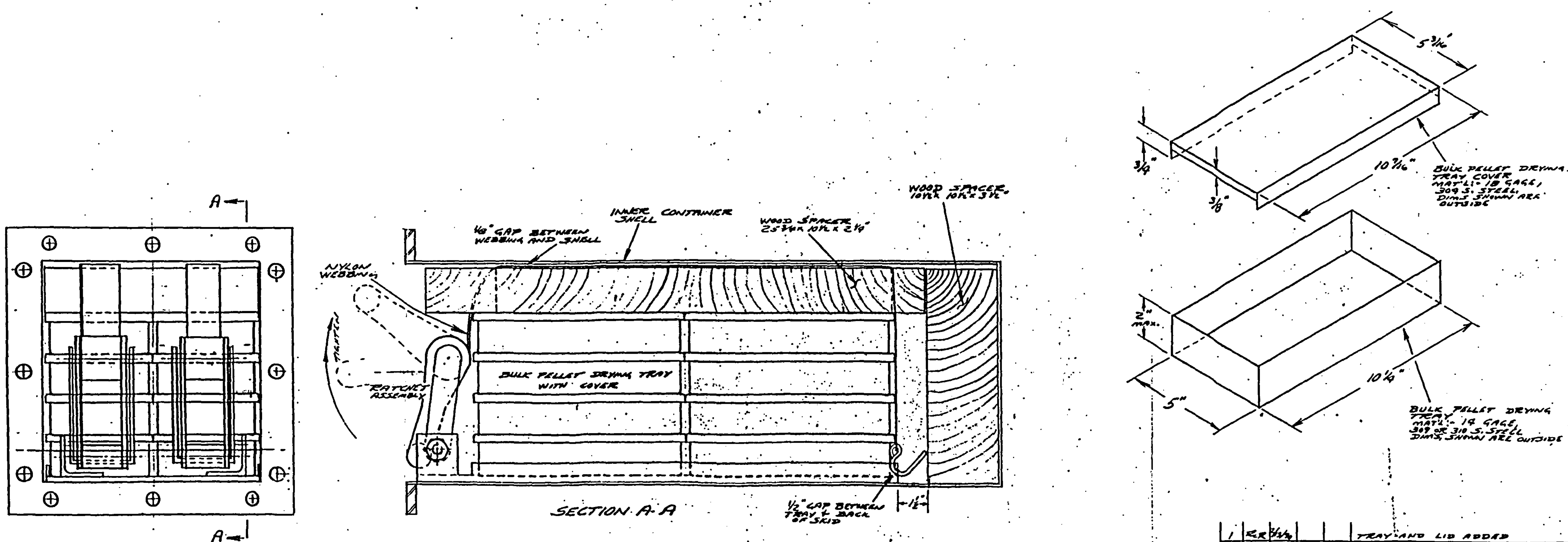
CE POWER SYSTEMS
COMBUSTION ENGINEERING INC
NUCLEAR POWER SYSTEMS

CUSTOMER
NEXT ASSY
SUPERSEDES
JOB NO. 776219
COMPONENT CODE
SCALE 1/4

DRAWN BY Sailey 8/21/81
CHECKER
APPROVAL 9/4/81

TITLE PELLET TRAY HOLDER
DWG NO. NFM-D-4263 REV. 02
SHEET 1 OF 1

8 7 6 5 4 3 2 1



REV.	BY	DATE	APP'D	DATE	DESCRIPTION
1	RLR	3/1/90			TRAY AND LID ADDED

DRAWN BY R L REED — DATE 1-19-90
CHECKER
APPROVALS R W Crescenzo — DATE 1-19-90
SCALE 3/16" = 1" DO NOT SCALE DWG

COMBUSTION ENGINEERING
NUCLEAR POWER SYSTEMS

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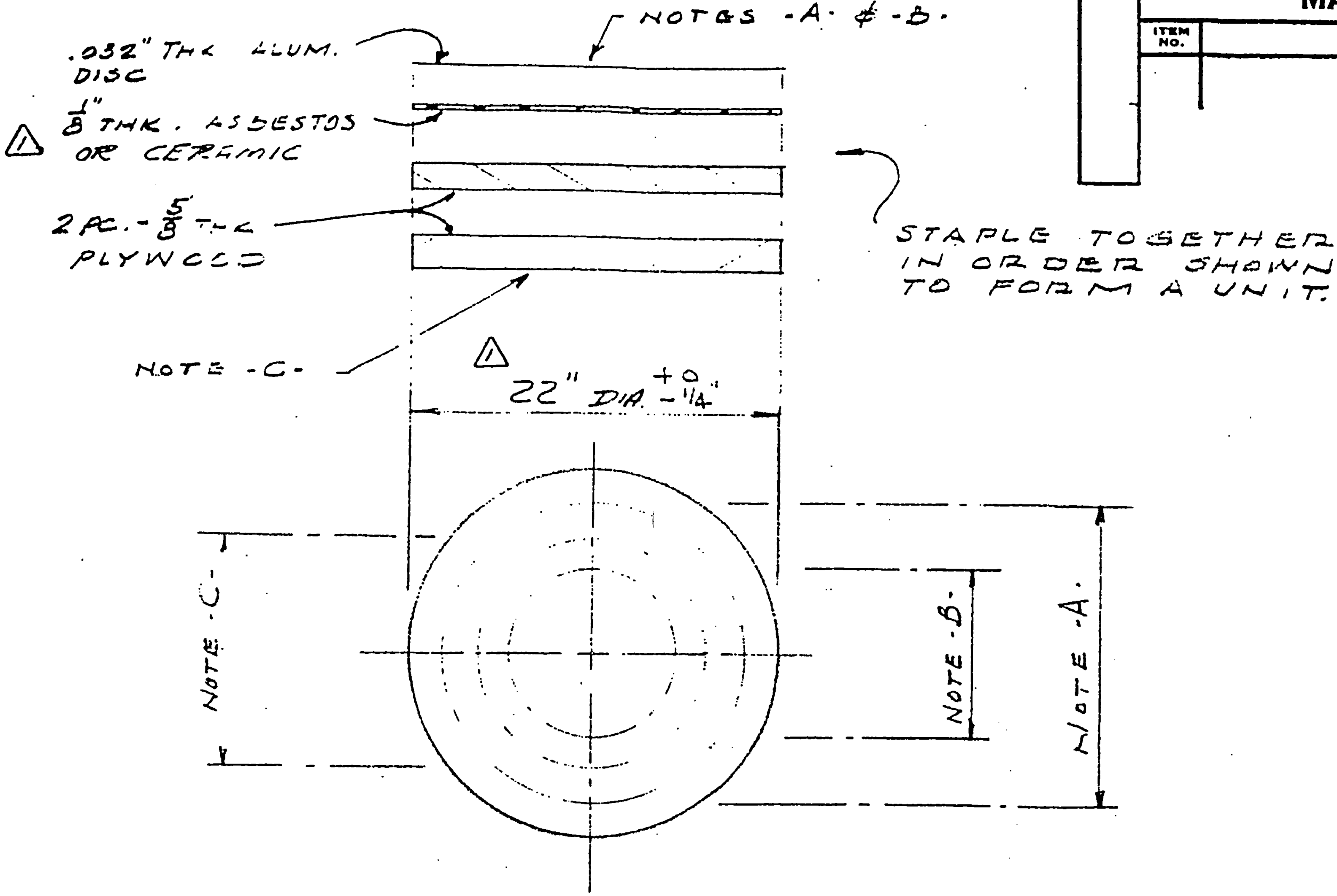
TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONAL ±
DECIMAL ±
ANGULAR ±

PELLET SHIPPING PACKAGE
16 TRAYS (PELLETS) IN 2901

SUPERSEDES:
SUPERSEDED BY:
COMPONENT CODE NO

DRAWING NO. D-5018-2001 — REV 1
SHEET 1 OF 1



MATERIAL FOR COMPLETE ASSEMBLY

ITEM NO.	PART DESCRIPTION	NO. REQ'D	SOURCE

NOTE A.. USING A 18" CIRCLE, PLACE ON 4" CTRS. 13/16" LG. STAPLES.

NOTE B.. USING A 10" CIRCLE, PLACE ON 3" CTRS. 13/16" LG. STAPLES.

NOTE C.. USING A 14" CIRCLE PLACE 4 @ 90° - 13/16" LG. STAPLES.

AMENDMANT DATE:
FEBRUARY 22, 1990
REV. 0
PAGE 1-4

REV.	BY	DATE	APP'D.	DATE	JOB NO.	DESCRIPTION	W.O. NO.
1	RLR	10/13/87				1/8" TK. ASB. OR CERAMIC WAS ASBESTOS - DIA'S WERE 21 3/4	

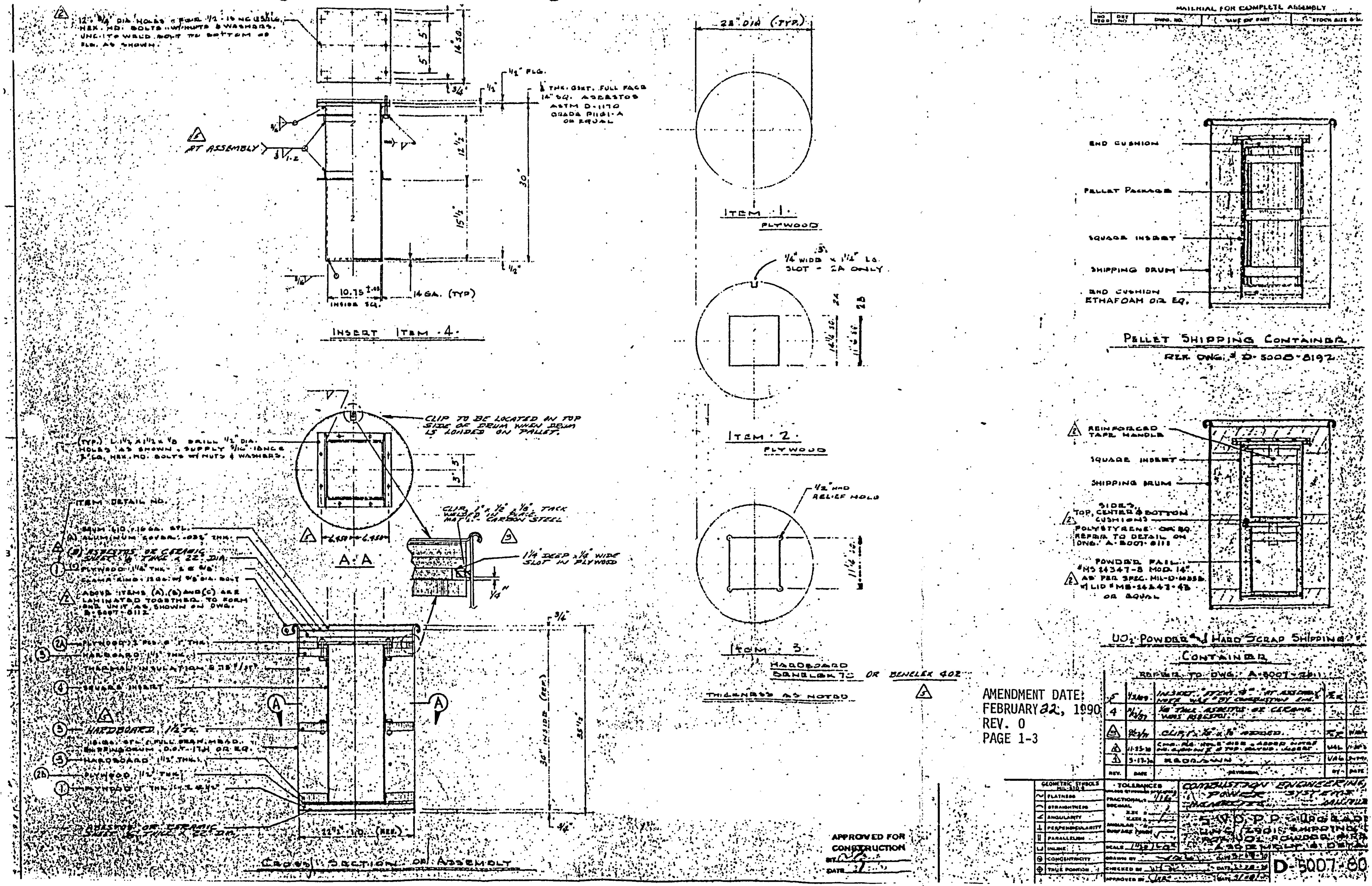
TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONAL ± 1/8
DECIMAL ±
ANGULAR ±
FINISH SYMBOL ASA ST'D

COMBUSTION ENGINEERING, INC.
POWER SYSTEMS
HEMATITE MISSOURI

SUGGESTED ASSEMBLY OF 2901 PLYWOOD INSERT

SCALE 1 1/2" = 1'-0" | DWN. BY YAL | APP'D. [signature]
DATE 11-24-70 | CHK'D BY RAL | APP'D.

B-5007-8112 REV. 1



AMENDMENT DATE:
FEBRUARY 22, 1990
REV. 0
PAGE 1-3